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GEOLOGICAL SECTION OF NEW JERSEY[1]

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PRE-CAMBRIAN ROCKS

The pre-Cambrian rocks of New Jersey comprise certain white crystalline limestones with closely associated quartzites and conglomerates and a great complex of granitoid gneisses, pegmatites, and magnetites which, because of their resistance to erosion, underlie the Highlands of the state.

Franklin limestone.—The Franklin limestone in its more common phases is a white, highly crystalline, coarsely granular limestone or marble, ranging in composition from a nearly pure carbonate of lime to a dolomite. Some of it is rather siliceous and in a few places thin beds of sandstone have been noted. At Franklin Furnace and Sterling Hill it contains large beds of zinc ore and magnetite veins are also present in a few places. Graphite is widely disseminated in the limestone, and with mica, pyroxene, and chondrodite frequently gives the rock a gneissic structure.

The Franklin limestone is unconformably overlain by basal members of the Cambrian system. It contains intercalated masses of gneiss, and is injected by numerous bodies of pegmatite, neither of which rocks are associated with the Cambrian formation. On the other hand, the Hardyston quartzite, the lowest member of the Cambrian, locally contains fragments derived from these pegmatites, and even fragments of the coarse-grained limestone itself. That the Franklin limestone was metamorphosed to its present condition long before the deposition of the lowermost Cambrian sediments has been abundantly demonstrated.

The gneisses.—The gneisses appear in many varieties and of different sorts so intricately mingled that detailed representation of their distribution on geologic maps is quite impracticable. The most noteworthy differences of appearance presented by them are those of color, and inasmuch as color-distinctions have been found to correspond broadly with fairly definite lithologic differences, they may be used as a guide in classifying the gneisses for the purposes of description and mapping.

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[1] In the preparation of this paper, I have drawn freely from the published reports of my associates on the Geological Survey of New Jersey and of those workers on the U. S. Geological Survey who have dealt with the problems of this area. To Dr. A. C. Spencer, in particular, am I indebted for data on the pre-Cambrian rocks.

All the dark gneisses which owe their color to the hornblende, pyroxene, or biotite which they contain have been grouped together under the name Pochuck gneiss. The second group, the members of which show brown-gray, bronzy, pink, and ocherous tones, is called the Byram gneiss. Here are included a great variety of granitoid or granite-like rocks related to one another and distinguished from the other gneisses by the presence of potash feldspar as an essential ingredient. A third group, the Losee gneiss, includes light-colored granitoid rocks, many of them nearly white, which contain lime-soda feldspar as an essential and characteristic mineral component.

These varieties of gneiss are seldom found in large masses free from intermixture with other sorts, but the different facies or varieties occur in tabular masses which are interlayered both on a large and on a small scale.

These gneisses, with few exceptions, correspond accurately in their mineralogical and chemical composition with common types of coarse-grained igneous rocks like the granites and diorites. The light-colored granitoid rocks included under the names of Losee gneiss and Byram gneiss are present in the largest amounts. There can be little doubt that they solidified in part out of invading silicate solutions or molten magmas. Evidence of crushing in the minerals of these gneisses is almost entirely wanting, and appearances strongly favor the belief that the gneissic foliation is original in these intrusive rocks of the pre-Cambrian complex.

The dark Pochuck gneisses have the composition of igneous diorites or gabbros, but whether they have been derived from igneous or sedimentary originals, or, as is believed, in part from both, their present characteristics have in most places been acquired by metamorphism, involving secondary crystallization. Foliation is everywhere present in these dark rocks, and parallel to this structure they are injected in all proportions by sheets of light-colored material similar in composition to phases of the Losee gneiss. They are also interlayered with both the Losee and Byram gneisses on a broad scale, and the Franklin limestones are similarly interlayered with the granitoid gneisses, so that these two sets of rocks—the dark Pochuck gneisses and the Franklin limestones—together seem to constitute a matrix holding the intrusive granitoid rocks in the form of relatively thin but extended plates.

Though the Pochuck gneiss and the Franklin limestone are both regarded as older than the granitoid gneisses, the original relations between them are not determinable.

Apparently the dark rocks were already foliated before they were invaded, because the interlayering of the granitoid materials is so regular that the presence of some structural control would seem to have been a necessity, but during this deformation the early texture of the rock was broken down, important addition or subtraction of elements may have occurred, and a later crystallization ensued contemporaneous with the crystallization of the injected material. The forces causing flowage probably continued to operate after crystallization had begun, and practically until it was complete, so that the injection of the granitoid material, the pressing out and kneading of the masses of the matrix, and the development of textural foliation in both were phenomena connected in origin with a single cause.

The Franklin limestone locally retains traces of original stratification, showing its sedimentary origin, but the lamination observed within masses of this rock is regarded mainly as a sort of flow structure developed through the crystallization of the limestone masses while they were being molded under the action of deforming stresses and at the same time traversed by mineral-charged waters derived from the invading Losee and Byram magmas. The facts are believed to warrant the conclusion that the white limestones and the various gneisses with which they are associated, together with the ore-deposits which they inclose, crystallized in their present state and received their present forms as geologic masses during a single period of regional deformation.

PALEOZOIC FORMATIONS

The Paleozoic rocks comprise representatives of the Cambrian, Ordovician, Silurian, and Devonian systems. They outcrop (*a*) in a few small areas southeast of the Highlands between the pre-Cambrian crystallines and the Mesozoic strata, (*b*) in narrow valleys within the Highlands, (*c*) in a board belt northwest of the Highlands, the latter area comprising the northern extension of the great Appalachian valley and the mountain west of it.

CAMBRIAN SYSTEM

Hardyston quartzite.—The Hardyston quartzite is the lowest formation of the Cambrian system, and is probably to be correlated with the Poughquag quartzite of Dutchess County, N. Y., and the Chickies quartzite of Pennsylvania. It is unconformable on the pre-Cambrian complex and is the oldest fossiliferous rock in New Jersey. It varies considerably in composition and thickness. Typically it is a quartzite, at many places conglomeratic and containing pebbles of quartz, feldspar, granite, gneiss, and slate. Locally the formation is a calcareous sandstone. It is usually but not invariably feldspathic. In some localities its arkose character is so marked that it is not readily distinguishable from a coarse granite. Beds of slate occur in its upper portion.

Its thickness ranges from a few feet to 200 or more, and it passes into the overlying sandstone through slaty or shaly layers, several of which are in places interbedded with limestone layers, so that its upper limits are indefinite. Since it contains a species of Olenellus, it is regarded as of Georgian (Lower Cambrian) age.

Kittatinny limestone.—The Hardyston quartzite grades upward into the thick magnesian Kittatinny limestone of the Kittatinny Valley. Above, it is limited by an unconformity at the base of the Jacksonburg (Trenton) limestone. The presence of thin shales and scattered seams of sandstone in the great mass of limestone shows an influx of land sediments at recurrent intervals during its formation.

The known fauna of the Kittatinny limestone is not extensive and is found at but few localities, but it suffices to establish the Cambrian age of the greater part of the formation. No Middle Cambrian fossils have been found, but as the Olenellus fauna of the Hardyston quartzite is considered to be of Lower Cambrian age, and as no evidence of a break in sedimentation has been observed, a Middle Cambrian fauna would naturally be expected between the Olenellus fauna below and the Dikelocephalus fauna above. In one locality a fauna of Ordovician (Beekmantown) age has been found in beds near the top of the Kittatinny limestone. This formation, therefore, where complete, represents a period extending from the middle or upper part of the Lower Cambrian to the lower part of the Ordovician, inclusive.

ORDOVICIAN SYSTEM

In northern New Jersey, as elsewhere in the great Appalachian valley, there is no sharp line of demarkation between the rocks of the Cambrian and those of the Ordovician system. The base of the Ordovician lies somewhere below the top of the Kittatinny limestone, as stated above, but the exact position of this division line cannot readily be determined.

Jacksonburg limestone.—Above the Kittatinny limestone, and separated from it by a break in sedimentation indicated by a calcareous basal conglomerate, is a dark-blue or black fossiliferous limestone, correlated with the Lowville, Black River, and lower Trenton limestone of the New York section and hitherto classed as "Trenton," some layers of which contain as much as 95 per cent. or more of calcium carbonate. Calcareous shales occur interbedded with these limestones and above them to the top of the formation. The sequence of conglomerate, limestone, and shale is a variable one, but, so far as observed, the transition to the overlying formation is always through a series of calcareous shales which become less and less limy.

The thickness of the Jacksonburg formation varies from 135 to 300 feet or more. It contains an abundant fauna, ninety-eight forms having been described by Weller. At the type locality the lower strata for a thickness of fifty-eight feet carry a Lowville–Black River fauna, and the higher beds have a lower Trenton fauna.

Martinsburg shale.—The Jacksonburg limestone passes upward through the calcareous shales mentioned above into a great thickness of shale, slate, and sandstone, which has heretofore been known as the "Hudson River slate," but which is now correlated with the Martinsburg shale of West Virginia and takes that name.

The formation ranges from the finest-grained shale and slate to fine sandstone. The former beds on the whole are black and more abundant in the lower part, whereas the sandstone beds are dark bluish-gray, many of them calcareous, and occur more commonly higher in the formation. The fine-grained rocks exceed the gritty beds.

Slaty cleavage is the predominant structure of the fine-grained beds, and the true bedding planes are in many places difficult to determine. At some horizons the planes of cleavage are so straight and parallel and the rock so even textured that commercial slates have been obtained in considerable quantities. The whole formation is so crumpled and cleaved that no accurate estimate of its thickness can be made, but it is probably at least 3,000 feet, and it may be more.

Four species of graptolites characteristic of the Normanskill fauna of New York have been found in the lower portion of the Martinsburg shale, so that the beds in which they occur are equivalent in age to the middle portion of the typical Trenton limestone of central New York. A few miles north of the New Jersey state line, Schizocrania and graptolites characteristic of the Utica shale of the Mohawk Valley have been found in beds close to the overlying Shawangunk conglomerate.

SILURIAN SYSTEM

Contrary to long-prevalent, and apparently well-established belief, the lower and middle portions of the Silurian system are not represented in New Jersey. Their absence in this and adjoining regions is indicative of somewhat widespread earth movements unaccompanied in this region by folding, which closed the period of deposition indicated by the Martinsburg sediments or possible overlying beds afterwards removed by erosion and raised the region above the zone of sedimentation. When deposition began again late in Silurian time, beds of coarse conglomerate were laid down, followed by sandstones, shales, and limestones, the earlier sediments being those of a low-grade delta in an arm of the Appalachian gulf.[1] These conditions of deposition prevailed with but slight changes of elevation into Devonian time.

Shawangunk conglomerate.—The Shawangunk conglomerate (the Oneida conglomerate of many previous publications) is chiefly a coarse quartzite and conglomerate composed of small white-quartz pebbles imbedded in a siliceous matrix. Its color is generally steel blue, but some beds have a yellowish tinge, and reddish layers occur near the top. Layers of black shale a few inches in thickness are locally intercalated between thick beds of conglomerate and grit. Between this formation and the Martinsburg shale there is a gap representing the upper part of the Ordovician and all of the Silurian below the Salina of the full New York section, but there is no marked divergence of dip and strike where the two formations outcrop in proximity, and the actual contact is nowhere exposed in New Jersey. The beds overlying the Shawangunk conglomerate are red sandstone and shale, and the transition from the Shawangunk is made through a series of alternating red sandstone and gray conglomerate, so that the upper limit of the Shawangunk is not sharply defined. Its thickness is probably from 1,500 to 1,600 feet.

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[1] Clarke, *N. Y. State Museum Bulletin 107*, p. 303.

So far as known, the formation is barren of fossils in New Jersey, but at Otisville, N. Y., a euryterid fauna has been found in the black shale intercalated with the conglomerate. In the Otisville section this fauna, which elsewhere appears only and briefly at the base of the Salina, repeats itself many times through a thickness of 650 feet.[1] The Shawangunk conglomerate is followed by 2,500 feet or more of shales and limestones also referable to the Salina; hence for this region it represents only the lower portion of that group.

High Falls formation.—The red sandstone and shale which immediately overlie the Shawangunk conglomerate have until recently been regarded as the equivalent of the Medina sandstone of New York and have been so called, but, for the reasons just cited, it is evident that they are much younger than Medina and that they must be included in the Salina group. Moreover, they lie some distance below a limestone which is correlated with the Cobleskill of the New York section. The name High Falls has been applied to the red shales that overlie the Shawangunk conglomerate in Ulster County, N. Y., and has been adopted for New Jersey in place of Medina, which is not applicable.

The lower beds consist of a hard red quartzitic sandstone, intercalated with some green or gray sandstones and softer red shales which become more abundant in the upper part of the formation. The formation has an estimated thickness of 2,300 feet at Delaware Water Gap. It is not known to contain fossils, but its age is fixed by its stratigraphic position.

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[1] Clarke, *op. cit.*, p. 303.

Green Pond conglomerate.—The formation known as the Green Pond conglomerate occurs in an isolated belt of Paleozoic rocks which extends through the middle of the pre-Cambrian Highlands of New Jersey. In constitution it is similar to the Shawangunk conglomerate, with which it is correlated, but, inasmuch as it is still an open question whether the Paleozoic strata of the Green Pond Mountain region were once continuous with the great mass of Paleozoic sediments which lie some distance to the northwest, or whether the Green Pond region represents a separate basin shut off on the northwest from the large Paleozoic sea although communicating with it to the northeast, it has seemed best to retain for the present at least both Shawangunk and Green Pond as names for these conglomerates in their respective fields.

Longwood shale.—Immediately above the Green Pond conglomerate, and conformable with it, is a soft, red shale, in which an irregular cleavage is usually so highly developed that the bedding planes can be determined only with difficulty. The formation is not known to contain fossils, but, as it rests directly upon the Green Pond conglomerate and is followed by a limestone carrying a Salina fauna, it is probably of Salina age. Its stratigraphic position is, in general, the same as that of the High Falls formation, but the two may not be exactly synchronous.

FORMATIONS ABOVE THE HIGH FALLS AND LONGWOOD SHALES

The higher Silurian and the Devonian formations of New Jersey occur either in Wallpack Ridge, which lies along the northwestern border of the state in the upper Delaware Valley, or in the narrow belt of Paleozoic rocks in the midst of the Highlands in the Green Pond Mountain region. In Wallpack Ridge they aggregate 1,300 feet or more, while in Green Pond Mountain region they have a thickness of about 4,000 feet, of which all but 250 feet are referable to beds higher than any of those along Wallpack Ridge.

Poxino Island shale.—The top of the High Falls shale in New Jersey is everywhere buried by glacial drift which also conceals the beds immediately superjacent. The next recognizable formation is the Poxino Island shale, a buff or greenish calcareous shale in thin layers and non-fossiliferous so far as known. Its outcrops along the base of Wallpack Ridge in the upper Delaware Valley are few, small, and widely separated, and very little is known regarding it. In the adjoining portion of Pennsylvania it is reported to be 200 feet in thickness, and to rest on a thin limestone formation which in turn rests on the High Falls shale. It is not known to occur in the Green Pond Mountain region.

Bossardville limestone.—A fine-grained, compact, bluish-gray, banded limestone, known as the Bossardville limestone, lies conformably upon the Poxino Island shale in Wallpack Ridge. It increases in thickness from 12 feet at the New York state line to about 100 feet where it crosses the Delaware River into Pennsylvania. Owing to its marked banding it was for many years known as the "Ribbon" limestone and was correlated by Cook and later geologists with the Ribbon or Manlius limestone at Rondout, N. Y. In reality it lies below the Manlius limestone. It is only sparingly fossiliferous but is immediately succeeded by a series of beds containing a well-defined Salina fauna. It has not been recognized in the Green Pond Mountain belt, but this may be from lack of exposures.

Decker Ferry formation.—Under the name *Decker Ferry formation* a series of beds has been described, which are chiefly limestones at the north and calcareous sandstones at the southwest. Their thickness is 52 feet at the Nearpass quarry near Tri-States where the section can be accurately measured. Thin bands of more or less fissile green shale separate the limestone beds. A thin band of red, crystalline, highly fossiliferous limestone occurs about the middle of the series and is a striking feature. The lower 42 feet of these beds as exposed at the type locality are correlated[1] with the Wilbur limestone (the so-called "Niagara" or "Coralline" limestone of Hall and other authors) and the "black cement" beds, i. e., the Salina "water lime" of the Rondout section of New York. These form the top of the Salina group, the base of which in New Jersey is the base of the

[1] Hartnagle, *New York State Museum Bulletin 69*, p. 1152.

Shawangunk conglomerate. The upper ten feet of the Decker Ferry series contain fossils, particularly in the lower half, which render necessary their correlation with the Cobleskill limestone of eastern New York.

In the Green Pond Mountain region isolated outcrops of impure limestone occur a short distance above the Longwood shale, which contain a fauna that correlates them with the lower beds of the Decker Ferry formation, i. e., to the part referable to the Salina group.

Rondout limestone.—Along the upper Delaware the beds immediately above the Decker Ferry limestone and referred to the Rondout consist of more or less earthy shales and limestones the thickness of which is 39 feet. They are usually only sparingly fossiliferous, although in some beds the crustacean Leperditia is abundant. A typically marine fauna, with an abundance of brachiopods, trilobites, etc., is conspicuously absent in these beds. In general lithologic features this formation resembles the Rondout as developed in New York state, but the cement beds which are so characteristic of this formation farther north are not present here.

Manlius limestone.—The Rondout is succeeded conformably by a somewhat thin-bedded, knotty, dark-blue or almost black limestone, 34 to 35 feet thick where best exposed. It is the bed which constitutes the quarry stone of the Wallpack Ridge and its outcrop is marked by a line of quarries and lime kilns. It is referred to the Manlius or "Tentaculite" limestone of the New York series, although well-preserved specimens of the characteristic fossil *Tentaculites gyracanthus* Eaton are rare. In the lower beds there is evidence of evironmental conditions similar to those of the Rondout. In the middle portion, Leperditia is still abundant, but is associated with a prolific brachiopod fauna, suggestive of the recurrence of more typical marine conditions. In the upper beds Leperditia has entirely disappeared, and the fauna is normally marine. No beds referable to the Rondout or Manlius have been detected in the Green Pond Mountain region, although their attenuated representatives may occur.

THE DEVONIAN

The Devonian formations of the upper Delaware Valley are of marine origin and are chiefly fossiliferous calcareous shales and limestones having a thickness of about 1,000 feet. Those of the Green Pond Mountain region are chiefly arenaceous shales, sandstones, and conglomerates, carrying comparatively few fossils, and aggregating over 4,000 feet in thickness.

The Helderbergian or lowermost Devonian faunas in New Jersey are essentially the same as those in New York, and the same faunal zones are recognized. The first formation carrying these faunas is the Coeymans limestone.

Coeymans limestone.—In the Nearpass section, the Coeymans limestone has an estimated thickness of forty feet, though only the lower beds are exposed. It rests conformably upon the Manlius limestone from which it differs lithologically in its coarser and more crystalline texture and lighter color. Frequently more or less chert is mingled with the limestone. The Coeymans fauna is far more prolific than that of the Manlius and differs markedly in composition, the most characteristic species being *Gypidula galeata.* A coral bed carrying more or less completely silicified masses of *Favosites helderbergiae,* and a concentrically laminated stromatoporoid occurs in the base of the formation.

Stormville sandstone.—In the southern half of the Wallpack Ridge in New Jersey, a thin sandy layer occurs at the top of the Coeymans limestone. It is in general an inconspicuous formation owing to its thinness and heavy deposits of glacial drift. It becomes more conspicuous toward the south and according to White[1] it gradually replaces the overlying calcareous and shaly strata until it occupies the entire interval between the Coeymans limestone and the Oriskany sandstone. It has not been recognized in the Nearpass section near Tri-States nor at any point north of Hainesville, N. J.

New Scotland beds.—The New Scotland beds which overlie the Coeymans limestone in the Nearpass section consist of about 20 feet of a very hard cherty limestone followed by a series of calcareous shales, having an estimated thickness of 140 feet. Nowhere in the state is there exposed a continuous section of these beds as is the case with several of the lower formations. The fauna is a prolific one, and is especially characterized by the abundant representation of the genus Spirifer. Its differences from the Coeymans fauna are of such an essential character as to indicate a separate immigration from the exterior into this region.[1] As indicated above, south of Hainsville, a thin sandy bed intervenes between the Coeymans limestone and the New Scotland beds and gradually replaces the latter. At Flatbrookville, where these strata cross the Delaware into Pennsylvania, the lower cherty limestone member of the New Scotland beds has disappeared, and the Stormville sandstone contains a fauna characterized by *Spirifer macropleurus*.

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[1] Second Geol. Surv. Penn., *Rep. G 6*, pp. 132, 133.

Becraft limestone.—A hard, gray, cherty limestone overlies the shaly layers of the New Scotland beds, forming a resistant layer which outcrops frequently along Wallpack Ridge. Its entire thickness has never been observed, but it is estimated to be about twenty feet. Its fauna is closely allied to that of the New Scotland beds, a few new forms appearing and a few old ones disappearing. There is also some difference in the proportionate number of individuals of some species, notably of *Leptaena rhomboidalis* which becomes especially abundant. The bed is correlated with the Becraft limestone of New York.

Kingston or Port Ewen beds.—A series of strata, nowhere exposed, occupies the interval between the Becraft limestone and the base of the Oriskany. They are probably shaly beds which easily disintegrate and thus become covered with débris. Their thickness is roughly estimated as eighty feet. The only basis for their correlation is their position which corresponds to that of the Port Ewen (Kingston) beds of New York. In Pennsylvania, the same beds have been called the Stormville shales by White.[2]

Oriskany formation.—A series of strata, aggregating about 170 feet in thickness, succeed the Port Ewen beds and are referred to the Oriskany. They are for the most part siliceous limestones, but the summit of the formation along the southern half of the Wallpack Ridge becomes a sandstone. The arenaceous facies is said to become more marked to the southwest in Pennsylvania and to embrace lower and lower beds until all the strata to the top of the Coeymans limestone are sandstones. The fauna of the Oriskany beds in New Jersey comprises three well-defined faunal zones, the lowest characterized by *Dalmanites dentatus*, the second by *Orbiculoidea jervensis*, and the third by the great abundance of *Spirifer murchisoni.*

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[1] Weller, N. J. Geol. Survey, *Paleontology*, Vol. III, p. 90.

[2] Second Geol. Surv. Penn., *Rep. G 6*, p. 131.

In the Nearpass section the beds bearing the *Dalmanites dentatus* fauna are about 30 feet thick and form the crest of a high ridge which is the southern extension of the "trilobite ridge"[1] east of Tri-States. There is a mingling of Helderbergian and Oriskanian forms in this fauna, and there has been some difference of opinion as to whether these beds should be placed in the Port Ewen or Oriskany, but recent workers[2] unite in referring them to the Oriskany.

Esopus grit.—The Esopus grit which overlies the sandstones and siliceous limestones of the Oriskany forms the crest of Wallpack Ridge for the greater part of its extent in the state. It is a nearly black gritty rock with well-developed cleavage, which obscures the bedding planes. The fucoid "cauda galli" markings can frequently be recognized on the bedding planes when the latter can be distinguished. Apart from these markings fossils are very rare. The average thickness of the formation in New Jersey is estimated to be 375 feet.

Onondaga limestone.—The Onondaga limestone overlies the Esopus grit along the northwestern slope of Wallpack Ridge. Toward its base the formation is somewhat shaly and there is apparently a rather gradual transition from the grit to the limestone. The latter is hard, cherty, and regularly bedded in layers ranging from three inches to one foot in thickness. The beds are assigned to the Onondaga on the basis of their position and lithology rather than faunal evidence, since the recognizable forms are not sufficiently characteristic for close correlation.

Marcellus shale.—Fissile black shale, referable to the Marcellus, has been reported to occur in New Jersey along the bed of the Delaware River a few miles below Port Jervis, but in recent years the exposures have apparently been buried by silting-up of the channel. This is the highest of the Devonian beds exposed in the state along the Delaware River, but in the Green Pond Mountain area still younger beds occur.

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[1] Shimer, *New York State Museum Bulletin 80*, pp. 175 f.

[2] Weller, Geol. Surv. of N. J., *Paleontology*, Vol. III, p. 96. Shimer, *op. cit.*, p. 184.

DEVONIAN FORMATIONS IN THE GREEN POND MOUNTAIN AREA

Kanouse sandstone.—The Kanouse sandstone, the lowest Devonian formation of the Green Pond Mountain region, is a thick-bedded, fine-grained conglomerate below, and a greenish sandstone above, having a thickness of about 215 feet. Although fossils are not rare, yet as a rule they are obscure, and many of them are so greatly distorted that their identification is impossible. So far as recognized they indicate an Onondaga fauna, and these beds may be interpreted as the shoreward correlatives of the Onondaga limestone. It is the formation which in the New Jersey Geological Survey reports has been called the Newfoundland grit.

Its outcrops form a narrow belt parallel to the Decker Ferry limestone, but separated from it by a narrow interval. In the upper Delaware Valley, as noted above, there are seven formations aggregating nearly 900 feet in thickness between the Decker Ferry and the Onondaga. In the Green Pond Mountain region none of these has been recognized and, if present at all, it can be only in very attenuated form.

Pequanac shale.—The Kanouse sandstone apparently grades upward into a black and dark-gray, thick-bedded, slaty shale (the "Monroe" shale of Darton and others). Cleavage is usually strongly developed so that the bedding planes are not always readily discernible. The thickness is estimated at 1,000 feet. This formation is probably conformable upon the Kanouse sandstone, but the contact has nowhere been observed. It contains a somewhat meager fauna among which, however, is the characteristic Hamilton species, *Tropidoleptus carinatus*, so that its reference to this period is beyond question.

Bellvale sandstone.—The Bellvale sandstone is scarcely more than a continuation of the Pequanac shale, but the beds are coarser and more sandy. The average thickness is estimated at 1,800 feet. The few fossils found are all Hamilton species.

Skunnemunk conglomerate.—The Bellvale sandstones grade upward into a coarse, purple-red, massive conglomerate, the white-quartz pebbles of which are sometimes 6 or 7 inches in diameter Beds of red, quartzitic sandstone alternate more or less frequently with the conglomerate and there are many gradations between the two. It forms the great mass of Bearfort Mountain in New Jersey and of Bellvale and Skunnemunk mountains in New York. It is the youngest Devonian formation in New Jersey and rests upon beds known by their fossils to be of Hamilton age. Whether it is the exact equivalent of the Chemung-Catskill cannot be determined.

STRUCTURE OF THE PALEOZOIC FORMATIONS

The Paleozoic rocks have the northeast-southwest structure lines characteristic of all parts of the Appalachian province, due primarily to a system of folds and faults whose trend is in that direction. The folds are rarely symmetrical, southeastward dips being usually less steep than northwest dips, so that the axial planes are inclined to the southeast. The folding took place during the Appalachian revolution and is most marked in the beds farthest southeast and diminishes rapidly to the northwest. Some overthrust faulting occurred during the folding, so that now isolated masses of Kittatinny limestone rest upon the Martinsburg shale. The more conspicuous dislocations, however, are due to nearly vertical faults parallel or oblique to the axes of the fold, by which the northwest side has been usually uplifted relatively to the southeastern. These faults are referred to disturbances occurring at the close of the Triassic sedimentation.

TRIASSIC SYSTEM

The Mesozoic era is represented by formations referable both to the Triassic and to the Cretaceous systems. The Triassic rocks occupy a broad belt southeast of the Highlands and extend across the north-central portion of the state from northeast and southwest, their southeastern margin being approximately a line drawn from Trenton to Jersey City. They comprise both sedimentary and igneous rocks, the former chiefly shale, the latter extrusive basalt and intrusive diabase. They rest unconformably upon the early Paleozoics and pre-Cambrian crystallines and along their southeastern margin they are in part overlaid conformably by beds of Cretaceous age. The structure is monoclinal, the strata being inclined at low angles to the northwest, but locally broad, shallow folds have been developed. The beds are cut by many nearly vertical normal faults, the amount of dislocation varying from a few inches to several thousand feet. The rocks are sparingly fossiliferous, footprints of reptiles, a few species of fish, and a small crustacean being the chief elements of a meager fauna.

Three divisions have been made on lithologic grounds: at the base the *Stockton* beds, comprising arkosic conglomerates and sandstones with some shales; above these the *Lockatong* beds, consisting of black shales, hard, massive, dark argillites, flagstones, and occasional very impure, thin, limestone layers; and at the top a great thickness of very soft argillaceous red shale, the Brunswick beds, which are more typical of the whole series than either of the other groups. Massive conglomerates at various points, chiefly along the northwest border adjoining the Highlands, replace these types at various horizons. Ripple marks, mud cracks, rain-drop impressions, reptile footprints are not uncommon in the finer shales, and cross-bedding, plunge and flow structure, and rapid variations of texture are characteristic of the coarser beds.

These sediments have been regarded as (1) deposits in broad shallow estuaries in which subsidence went on *pari passu* with deposition; (2) lake sediments; (3) sediments in orographic valleys made by rivers of enormous width; and (4) subaërial stream deposits on a piedmont plain fronting a newly uplifted crystalline foreland from which numerous short but vigorous streams derived the sediments which were deposited in coalescing alluvial fans. Occasional downward movements of warping or faulting gave opportunity for local thickening of the deposits along the belts affected. The latter view is perhaps the more likely, although the first still has its adherents.

Four or more periods of eruption at considerable intervals gave rise to three great sheets of basalt each of which is conformable to the beds on which it rests, and each of which was buried by continued sedimentation. The intrusion of a thick sill of diabase obliquely across the strata occurred toward the close of sedimentation. Uplift accompanied by northwestward tilting and normal faulting terminated the deposition of these beds, caused the displaced strata to be beveled off across the upturned edges, revealing the edges of the buried basalt and diabase sheets, and brought up again the crystallines which in adjoining states, and to some extent in New Jersey, skirt the southeast border. The constructional topography due to these orographic movements was largely, if not entirely obliterated by erosion previous to the deposition of the Cretaceous sediments which overlap the beveled edges of the Triassic beds along their southeastern margin, and which formerly extended much farther northwestward than at present.

THE CRETACEOUS SYSTEM

The Cretaceous strata rest unconformably upon the beveled edges of the Triassic shales along their southeastern margin. They comprise unconsolidated sands and clays, which dip 50 to 25 feet per mile to the southeast, and which have an aggregate thickness of from 500 to 1,000 feet, the greater thickness being formed in the northern portion. The lowermost beds are referred to the upper part of the Lower Cretaceous and are of non-marine origin. The middle and upper portions, however, belong to the Upper Cretaceous and contain an abundant marine fauna.

Raritan formation.—The Raritan formation is extremely variable, consisting chiefly of light-colored sands and clays, some of the latter being highly refractory. There is on the whole a preponderance of clays in the lower and of sands in the upper half of the series. Since it was laid down on an irregular surface its thickness is variable, ranging from 150 to 250 feet at the outcrop, but increasing to the southeastward, as shown by well-borings, to over 500 feet. Northeast of Trenton it rests unconformably upon the beveled Triassic shales, but farther southward upon the ancient crystallines of early Paleozoic or pre-Paleozoic age, and perhaps at undetermined points still farther south on earlier Cretaceous beds. It dips 40 to 50 feet per mile to the southeast, the basal beds having the steeper inclination. The known fauna is very limited, consisting of a few pelecypods, some of which are brackish-water types while two are typically marine, a plesiosaurian bone, and possibly an insect. Its flora embraces a wide range of genera and species, especially of dicotyledons, many of which are closely related to modern forms. It has been regarded by Ward as late Lower Cretaceous and, therefore, approximately equivalent to the Gault of England.

Magothy formation.—The lignitic sands and clays referred to the Magothy formation and regarded as the lowermost of the Upper Cretaceous formations were until recently included in the Raritan.

On the shores of Raritan Bay they attain a thickness of 175 feet but diminish to the southwest and along Delaware River are only 25 or 30 feet. They are slightly glauconitic near the top. The Magothy rests unconformably on the Raritan but the discordance is not great and indicates only a slight epeirogenic movement. A marine fauna of 43 species, possessing close affinities to that of the Ripley beds of the south and to the Senonian of Europe, is found on the shores of Raritan Bay, but farther southwest the deposits are apparently estuarine. The flora is abundant and presents a much more recent aspect than that of the Raritan. It is regarded by paleobotanists as showing Cenomanian affinities.

Merchantville clay.—The Merchantville is a black, glauconitic, micaceous clay, usually greasy in appearance and massive in structure, weathering to an indurated brown earth. Its thickness is about 60 feet. It is conformable to the Magothy formation below and the Woodbury clay above. Its fauna is large and varied and although it contains many forms common to the beds above and below, its most characteristic species are conspicuous for their absence or great rarity in the adjoining strata. The Merchantville clay represents the lower part of the Crosswicks clay of Clark, forms the base of the Clay-marl series of Cook, and is the lowest of the five formations in New Jersey which are correlated with the Matawan formation of Maryland.

Woodbury clay.—The Woodbury is a black, non-glauconitic, jointed clay about 50 feet thick, which weathers to a light chocolate color, and when dry breaks into innumerable blocks, frequently with a conchoidal fracture. Its fauna of 95 marine species is more closely allied to that of the Magothy than to the subjacent Merchantville. It is conformable both with the Merchantville below and the Englishtown sand above. It is the upper part of the Crosswick clay of Clark, and forms part of the Clay-marl series of Cook. It is also one of the formations correlated with the Matawan of Maryland.

Englishtown sand.—The Englishtown is a conspicuous bed of white or yellow quartz sand slightly micaceous and sparingly glauconitic. Locally it contains thin laminae of fine brittle clay. So far as known it contains no fossils. It decreases in thickness from 100 feet near Atlantic Highlands to less than 20 feet in the southern portion of the state. It represents the lower part of the Hazlett sand of

Clark, and forms a part of Cook's Clay-marl series. It was formerly called the Columbus sand and is the equivalent of a part of the Matawan formation.

Marshalltown clay-marl.—The Marshalltown ranges from a black sandy clay to an argillaceous greensand marl. Locally it is abundantly fossiliferous, its characteristic species being in part recurrent forms from the Merchantville, and in part a new element, which recurs again in a higher formation although absent or inconspicuous in the immediately succeeding beds. Its thickness is 30 to 35 feet. It is a portion of the "laminated" sands which formed the upper part of the Clay-marl series of Cook, although in the southwestern portion of the state he referred these beds to the Navesink (Lower) marl. It was included in Clark's Hazlett sands, a subdivision of his Matawan.

The Wenonah and Mount Laurel sands.—Above the Marshalltown clay-marl there is a considerable thickness of sand regarding which there has been some difference of opinion. The terms Wenonah and Mount Laurel have both been applied to them in whole or in part. Lithologically they are not sharply differentiated from each other, although the lower part (Wenonah) is generally a fine micaceous sand and the upper part (Mount Laurel) is coarser and contains considerable greensand. Paleontologically, however, they are quite distinct. The Wenonah fauna is largely recurrent from the Woodbury, with comparatively few prominent species common either to the Marshalltown below or the Mount Laurel and Navesink above. The same elements are prominent again still higher in the Red Bank. The Mount Laurel fauna is identical with that of the Navesink above, and is closely allied to the Marshalltown, but contains a foreign element, chief among which is the cephalopod *Belemnitella americana* and the brachiopod *Terebratella plicata*, so that the indistinct lithological line between the Wenonah and Mount Laurel sands is of considerable paleontological singificance. The combined thickness of these formations is 40 to 80 feet, the Mount Laurel being limited to a very thin bed at Atlantic Highlands (Cook's sand-marl) but increasing much in thickness toward the southwest. The Wenonah sand is the highest bed correlated with the Matawan of Maryland, while the Mount Laurel is the base of the Monmouth.

Navesink marl.—The Navesink marl consists of greensand marl, mixed with varying amounts of quartz sand and fine earth, the latter of which contains much carbonate of lime in a powdery state. Where purest the marl has a dark-green or bluish-black color. The upper part of the bed contains progressively less greensand and is more clayey. The fauna is large (121 species, Weller), and is allied with that of the Marshalltown and Merchantville beds, while the characteristic forms of the Magothy, Woodbury, and Wenonah are absent. The formation has a maximum thickness of about 40 feet, diminishing southward to 25 feet or less. It corresponds in general to Cook's Lower Marl, although locally beds referred by him to the Lower Marl have proved to be the Marshalltown. It rests conformably upon the beds below and grades upward into the Red Bank sand, or where that is absent into the Hornerstown marl.

Red Bank sand.—The Red Bank sand is for the most part a fairly coarse ferruginous yellow and reddish-brown quartz sand, locally indurated by the infiltration of iron. The lower beds are in many places somewhat clayey. The Red Bank fauna has come chiefly from these clayey layers. In its essential features it is a recurrence of the *Lucina cretacea* fauna of the Magothy, Woodbury, and Wenonah formations, and differs in important respects from the Navesink fauna immediately below. It occurs only in the northern part of the coastal plain where its maximum thickness is 100 feet, but it thins out and disappears midway across the state. It is the Red Sand of Cook and earlier writers but does not include certain sands in the southern portion which were correlated by him with the Red Sand of Monmouth County. With the overlying Tinton bed, it is the uppermost of the beds correlated with the Monmouth formation of Maryland.

Tinton bed.—A lense of green indurated clayey and sandy marl, having a thickness of from 10 to 20 feet, overlies the Red Bank sand in Monmouth County. Its fauna is more closely allied to that of the Navesink than of the Red Bank and is characterized by large numbers of crustacean claws of the genus Callianassa. It is Cook's "indurated green earth," regarded by him and other writers as a part of the Red Sand, but in view of its faunal and lithologic differences it deserves some separate recognition.

Correlation of the Magothy-Tinton beds.—The assemblage of fossils making up the faunas of the beds from the Magothy to the

Tinton inclusive constitute a larger faunal unit, much more sharply separated from the faunas above and below than are any of its constituent faunules from each other. Weller has shown that this larger faunal unit is made up of two or more distinct facies, one of which, the Cucullaea fauna, is characteristic of the more glauconitic beds; namely, the Merchantville, Marshalltown, Navesink, and Tinton, while the other facies characterized by *Lucina cretacea* or its associates occurs in the clays or clayey sands of the Cliffwood, Woodbury, Wenonah, and Red Bank formations. The two facies existed contemporaneously and migrated backward and forward across the present outcrop of these beds in New Jersey as deeper or shallower water conditions prevailed. The larger faunal unit is closely related to the Ripley fauna of Alabama, Mississippi, and Texas. On faunal evidence all the formations from the Magothy to Tinton inclusive are referable to the Senonian of Europe, although on floral evidence the Magothy might be regarded as Cenomanian.

Hornerstown marl.—The Hornerstown marl is a bed of glauconite with clay and sand and not differing materially from the Navesink. Its fauna is meager but is totally different in its essential characteristics from the faunas of all the underlying formations. *Terebratula harlani*, *Cucullaea vulgaris*, and *Gryphaea dissimilaris* (Weller) are characteristic forms. A shell bed at the top of the formation is a conspicuous feature at many localities. The thickness is 30 feet or less. At the north it rests with apparent conformity on the Tinton, where that is absent it lies on the Red Bank, and farther south it is continuous with the Navesink, owing to the disappearance of the Red Bank. It is conformably overlain by the Vincentown except where overlapped by Miocene formations. It is the Middle Marl of Cook, the Sewell marl of Clark, and is a part of the Rancocas group.

Vincentown sand.—The Vincentown sand presents two phases, a calcareous or limesand, semi-indurated, and largely a mass of broken bryozoan, echinoid, coral, and other calcareous remains, and a glauconitic quartz-sand phase. The two phases occur in alternating layers, although the former is more common in the basal portion, particularly to the south, while the quartz-sand phase predominates in Monmouth County. The fauna of the limesand phase contains large numbers of bryozoa, echinoids, and foraminifera, while in the siliceous phase elements of the Hornerstown fauna occur in association with forms characteristic of the calcareous phase. Its thickness varies from 25 to 70 feet, but well-borings have shown that it thickens greatly down the dip· It rests conformably upon the Hornerstown marl and is overlain conformably by the Manasquan marl or overlapped by Miocene beds. It includes the "limesand" and "yellow sand" of Cook, the former of which was regarded by him as a part of the Middle Marl.

Manasquan marl.—The Manasquan marl in its lower portion (13–17 feet) is composed chiefly of glauconite, but the upper part (8–12 feet) is made up of very fine sand mixed with greenish-white clay, piles of which look like heaps of ashes—hence the name "ash marl." The fossils are not abundant and are poorly preserved, the commonest occurring also either in the Hornerstown or Vincentown. Its thickness is about 25 feet. It corresponds to the "green" and "ash" marls of Cook's Upper Marl bed and is the youngest of the Cretaceous formations exposed in New Jersey. It probably rests conformably upon the Vincentown and at most exposures is succeeded unconformably by Miocene or Pleistocene deposits, although locally it is overlain by a bluish marl of Eocene age without apparent unconformity.

Correlation of the Hornerstown, Vincentown, and Manasquan.—The faunas of these three formations are closely related, and form a larger fauna sharply separated from the Ripleyian fauna of the underlying Magothy and Tinton beds. This fauna has not been recognized south of Maryland. It shows certain affinities with the lower or Maestrichtian division of the Danian series of Western Europe (Weller).

EOCENE SYSTEM

Shark River marl.—Eocene deposits in New Jersey are limited in outcrop to small areas near Long Branch in Monmouth County where a mixture of greensand and light-colored earth 11 feet in thickness and carrying Eocene fossils rests without apparent unconformity upon the "ash" marl of the Manasquan. The conformity, however, is only apparent, well-borings indicating that the Shark River, as this formation has been called, probably overlaps the Cretaceous.

Clark[1] considers that it is not possible to correlate the Shark River marl with any other known Eocene deposits and regards them as probably older than the Eocene of Maryland. By some other authors, however, they have been placed above the Maryland Eocene.

MIOCENE SYSTEM

Beds of known Miocene age are widely distributed in the coastal-plain portion of New Jersey, where they overlap the Eocene and many of the Cretaceous formations. At the north they rest on beds ranging from the Eocene to the Hornerstown marl, while in the southern portion outliers are found upon the Mount Laurel sand.

Kirkwood formation.—Under the term Kirkwood have been included all beds of demonstrable Miocene age which outcrop in New Jersey. These beds vary lithologically in different regions, but they are predominantly fine micaceous quartz sands often delicately banded in shades of salmon-pink and yellow. Black, lignitic clays occur in many localities at or near the base. In the southern portion (Salem County) a thick (80–90 feet) bed of chocolate or drab-colored clay occurs, above which there are (or were formerly) exposures of a fine clayey sand containing great numbers of shells (the Shiloh marl of many reports), which, in the localities where it occurs, forms the upper bed of the Kirkwood. The thickness is about 100 feet or more along the outcrop. On the basis of the abundant fauna in the beds at Shiloh, the Kirkwood is believed to correspond in a general way with the Calvert formation of Maryland, the lowest division of the Chesapeake group.

Well-borings at Atlantic City, Wildwood, and other points along the coast have demonstrated the presence there of a great thickness of Miocene strata not apparently represented in outcrop. At Atlantic City clays, sands, and marls from 390 to 1,225 feet below tide carry Miocene fossils, and at Wildwood those from 300 feet to 1,090 feet and perhaps to 1,244 are Miocene. From the fossils it is evident that strata referable to the St. Marys, Choptank, and Calvert horizons of the Chesapeake group are present.

Cohansey sand.—Overlying the Kirkwood at its outcrop is a formation composed chiefly of quartz sand, locally with laminae and lenses of light-colored clay and occasional lenses of gravel. This formation outcrops over a wider area of the coastal plain than any of those heretofore discussed. Obscure casts of molluscan shells have been found in it, but these are of no value in determining its age. Plant remains from near Bridgeton indicate a flora comparable with that of certain European upper Miocene localities. It dips southeastward 9 or 10 feet per mile, and overlies the Kirkwood with seeming unconformity.

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[1] *Report of the State Geologist of New Jersey,* for 1893, p. 346.

Inasmuch as sands and clays similar to the Cohansey are revealed in borings along the coast and there overlie clays carrying Miocene fossils characteristic of the St. Marys, the highest division of the Chesapeake group, the Cohansey apparently belongs to a still later stage of the Miocene or perhaps even to the Pliocene. It is possible, however, that as now defined it may represent in part at least the shoreward phases of the fossiliferous Miocene clays found in the borings along the coast, and that it should be correlated with the Choptank and St. Marys of Maryland. In the light of all data at present available, however, the former view seems most probably the true one.

PLIOCENE SYSTEM

Beacon Hill formation.—Under the term Beacon Hill there were described certain beds of gravel and sand occurring as outliers on the higher hills of Monmouth County. Later the sand beds were correlated with the great body of sand now included in the Cohansey formation, leaving only the gravel in the Beacon Hill formation. It is chiefly quartz, but contains much chert and some hard sandstone and quartzite. The chert pebbles are uniformly much decayed and are frequently very soft. The quartz and quartzites are often more or less corroded. The formation occurs as isolated remnants on some of the highest hills of the coastal plain. It is perhaps to be correlated with the Lafayette formation farther south.

PLEISTOCENE SYSTEM

The Pleistocene formations of New Jersey are glacial and non-glacial, the former occurring in the northern counties, the latter chiefly on the coastal plain. The glacial or glacially derived deposits will first be considered.

GLACIAL DEPOSITS

Kansan or pre-Kansan drift.—Glacial drift, both stratified or unstratified, greatly antedating the moraines of the Wisconsin epoch, occurs more or less discontinuously south of the Wisconsin moraine, to a maximum distance of 23 or 24 miles. In the Highland belt it is thicker and more continuous in the wider valleys than on the ridges, while on the Triassic piedmont plain it caps isolated and more or less flat-topped hills in relations which indicate prolonged erosion, since its deposition. The great age of this drift is indicated by the fact that the main streams have sunk their channels 100 feet and have opened wide valleys on extremely gentle gradients since it was formed. Its complete oxidation and leaching and the disintegration in situ of even large bowlders of gneiss and granite deep within its mass are other evidences of its great age. It is believed to be at least as old as the Kansan drift and may be even older.

Wisconsin drift.—A great terminal moraine of the Wisconsin ice-sheet crosses the state from Perth Amboy to Belvidere. Narrow valley trains of glacial gravels characterize some of the southward drainage lines, notably Delaware Valley, and locally overwash plains are conspicuous topographic features. North of the moraine the rock surface is covered by the usual assemblage of drift deposits, stratified and unstratified. At least two definite halts in the ice retreat are marked by recessional moraines and valley trains which head in them. The warped shorelines of an extinct glacial lake in the upper Passaic Valley indicate a differential elevation of the northern part of the state of about 2 feet per mile, since the retreat of the Wisconsin ice-sheet.

NON-GLACIAL DEPOSITS

The non-glacial Pleistocene deposits consist of gravels, sands, and some clays, chiefly of fluviatile origin, but deposited partly at least in connection with estuarine conditions. Three formations have been differentiated, the Bridgeton, Pensauken, and Cape May, partly on lithologic and partly on topographic grounds. Each of these represents a period in which both erosion and deposition occurred in this region but in which deposition predominated. They were separated by intervals in which on the contrary erosion prevailed over deposition, although the latter did not cease. Consequently there are, in addition to the deposits referred to these formations, others accumulated during intervals of erosion, whose lithologic, topographic, and age relations are not so clear. Changes of elevation are believed to have accompanied and to some extent to have caused the alternate periods of erosion and deposition, but it is not believed that subsidence was so great as to have depressed all the region in which these beds are now found below sea-level.

Bridgeton formation.—The Bridgeton formation is essentially gravel and sand, the material having been derived from the Beacon Hill, Cohansey, Miocene, Cretaceous, Triassic, Paleozoic, and crystalline formations. Material from the crystallines and Triassic is almost uniformly friable and crumbles readily. Some bowlders are so large and of such a character as to have hardly reached their present position without the aid of floating ice. It occurs as outliers capping high hills, and on divides, and is manifestly now only a remnant of an ancient deposit in large part fluviatile and referable in time of origin to a very early glacial epoch.

The Bridgeton is comparable in a general way to the Sunderland of Maryland, although their limits may not be the same and somewhat diverse views of origin are held by workers in the respective fields. After the deposition of the Bridgeton, there was a long period of erosion during which much of the Bridgeton was removed, particularly in Delaware Valley and along the broad belt of low land stretching across the state from Bordentown and Trenton to Raritan Bay.

Pensauken formation.—The Pensauken formation is chiefly gravel and sand, although locally it contains beds of clay. It frequently much resembles the Bridgeton and cannot always be distinguished from it on lithologic grounds. Where both are present, however, it uniformly occurs at lower levels and has suffered less erosion. It obliterated the smaller and partially filled the larger valleys eroded in post-Bridgeton time, forming broad flood-plain deposits along the drainage lines. The coastal portion of the state was more or less submerged during this period of deposition but the Pensauken formation is conceived to be one due primarily to fluviatile rather than marine or littoral conditions. Since glaciated material occurs sparingly, it is correlated with a glacial epoch—one, however, which long antedated the Wisconsin drift sheet. In relation to other Pleistocene deposits, it corresponds roughly to the Wicomico of Maryland. Pensauken deposition was followed by a long period of uplift during which the formation was much eroded, nearly all of it being removed from areas favorably situated for erosion.

Cape May formation.—At a later time there was a slight submergence to the extent of 40 or 50 feet below the present stand of the land. During this period terraces were formed at many points along the coast and in valleys which were not submerged. The deposits of this stage constitute the Cape May formation and are believed to correspond in age with those of the last glacial epoch or possibly its later stages. The estuarine terraces along Delaware Bay are continuous with those along Delaware River above Trenton which head in the terminal moraine of the Wisconsin ice-sheet. While along the coast and lower Delaware River the terraces do not exceed 40 feet in height, and are lower than the Pensauken terraces in the same region, yet along the tributary streams they rise to much greater elevations, in some cases equaling that of the Pensauken or Bridgeton.

Since the deposition of the Cape May formation there has been an elevation of the land to something above its present level. Still more recently, subsidence has been in progress and is apparently now going on.

SECTION FOR NEW JERSEY

PLEISTOCENE

GLACIAL		NON-GLACIAL	
Wisconsin Drift	0–250+ feet	Cape May formation	0–20 feet
Unconformity		Unconformity	
Early Glacial Drift	0– 30+ feet	Pensauken formation	0–20+feet
		Unconformity	
		Bridgeton formation	0–30 feet
		Unconformity	

PLIOCENE ?

Beacon Hill gravel	Variable

MIOCENE ?

Cohansey formation	100–250 feet
(*Sand and clay lenses*)	
Unconformity	

MIOCENE

Kirkwood formation	100 feet
(*Sand and clay*)	
Unconformity	

EOCENE

Shark River marl	11 feet

CRETACEOUS

Manasquan marl	25 feet
Vincentown sand	25–70 feet
Hornerstown marl	30 feet
Tinton bed	10–20 feet
Red Bank sand	0–100 feet
Navesink marl	25–40 feet
Mt. Laurel sand	5–60 feet
Wenonah sand	35–20 feet
Marshalltown clay-marl	30–35 feet
Englishtown sand	20–100 feet
Woodbury clay	50 feet
Merchantville clay	60 feet
Magothy formation (*Sand and lignitic clay*)	25–175 feet
Unconformity	
Raritan formation	150–250 feet
(*Sands and variegated clays*)	
Great unconformity	

TRIASSIC

Brunswick shales	6,000–8,000 feet
Lockatong argillites	3,500 feet
Stockton arkose sandstones	2,300–3,100 feet
Three or more basalt flows and one or more intrusive diabase sills at various horizons. Total maximum thickness	3,000 feet
Great unconformity	

DEVONIAN

UPPER DELAWARE VALLEY		GREEN POND MT. REGION	
		Skunnemunk conglomerate	1,500± feet
		Bellvale sandstone	1,800 feet
Marcellus shale	Traces	Pequanac shale	1,000 feet
Onondaga limestone	Undet.	Kanouse sandstone	215 feet
Esopus grit	375 feet	Not recognized	
Oriskany formation (*Siliceous limestones and sandstones*)	170 feet	" "	

Kingston or Port Ewen shale	80 feet	“	“
Becraft limestone	20 feet	“	“
New Scotland beds (*Cherty limestone and calcareous shale*)	160 feet	“	“
Stormville sandstone	0–10± feet	“	“
Coeymans limestone	40 feet	“	“

SILURIAN

	Manlius limestone	35 feet	Not recognized	
	Rondout limestone	39 feet	“ “	
Salina	Decker Ferry limestone	52 feet	Decker Ferry limestone	
	Bossardville limestone	12–100 feet	Not recognized	
	Poxino Island shale	Unknown	“ “	
	High Falls shale	2,300 feet	Longwood shale	200+feet
	Shawangunk conglomerate	1,500 feet	Green Pond conglomerate	1,200–1,500 feet

Unconformity

ORDOVICIAN

Martinsburg shale	3,000 feet
Jacksonburg limestone	125–300 feet

Unconformity

Kittatinny limestone	2,500–3,000 feet

CAMBRIAN

Kittatinny limestone	
Hardyston quartzite	5–200 feet

Great unconformity

PRE-CAMBRIAN

Byram and Losee gneiss—rocks of various types, intrusive in older sedimentary rocks	Unknown thickness
Pochuck gneiss, in part intrusive, in part metamorphosed sediments	
Franklin limestone — white crystalline limestone penetrated and surrounded by younger intrusives	Unknown thickness